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EFFECTS OF PHOSPHORUS AND POTASSIUM FERTILIZERS ON

The Yield and Botanical and Chemical Composition of Seven Grass-Legume Mixtures

1952-1954

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CONTENTS

Page

Materials and methods. 1

Forage yields. 3
    Review of literature 3
    Results and discussion 4
    Summary. 10

Botanical composition of harvested forage. 11
    Review of literature 11
    Results and discussion 12
        Legume composition versus legume yield 17
        Weedy species. 17
    Summary. 17

Chemical composition of harvested forage 19
    Review of literature 19
    Results and discussion 21
        Potassium. 22
        Phosphorus 24
        Sodium 24
        Calcium. 24
        Magnesium. 26
        K/(Ca + Mg) equivalent ratios. 26
        Micronutrients 29
    Summary. 29

Summary. 30

Literature cited 31

Appendix

    Table 14.--Micronutrient composition of forage in first cutting, 1952. 36
    Table 15.--Protein content of the forage, 1952 37

EFFECTS OF PHOSPHORUS AND POTASSIUM FERTILIZERS ON THE YIELD AND BOTANICAL AND CHEMICAL COMPOSITION OF SEVEN GRASS-LEGUME MIXTURES

1952 - 1954

O. J. Hunt[1] and R. E. Wagner[2, 3]

Efficiency of production is becoming increasingly important in dairy and livestock farming. One of the greatest potentials for increasing this efficiency is through effective use of fertilizers on forage crops. On many soils of the Eastern States present fertilizer recommendations call for a phosphate-potash ratio of 1:2 or in many instances 1:3 for alfalfa and grass-legume mixtures. Only a few years ago recommendations of a 2:1 ratio or even phosphate alone were common.

More specific information is needed on rates and ratios of nutrient elements required by various species in mixtures under specific conditions. Such information becomes increasingly important as more fertilizer is applied to increased acreages.

The present investigation was initiated to determine the effect of rates and ratios of phosphorus and potassium on forage yield and botanical and chemical composition of several forage mixtures.

MATERIALS AND METHODS

The experiment was conducted at Beltsville, Md., on a Codorus silt loam. The chemical characteristics of the soil before initiation of the experiment are presented (table 1). The lime treatments brought about the greatest change in the soil in the 0- to 6-inch zone. The high-lime level changed the pH of this zone from 4.94 to 5.62 soon after application. After 3 years the pH was up to 6.48. The low-lime level had very little effect on pH; however, it did increase the Ca and Mg contents considerably in the 0- to 6-inch zone.

In the spring of 1951 seven forage mixtures were seeded in 6 3/4 by 21 foot plots on a well-prepared seedbed. The experimental design was a split-split-plot consisting of two lime levels designated as high lime and low lime, seven forage mixtures within each lime level, and eight fertilizer treatments within each mixture. The treatments were replicated 3 times.

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Table 1.--Soil analysis before experiment was initiated, 1951

[Average of 12 samples]

Chemical characteristic of soil	Depth of sampling 0-6 inches	Depth of sampling 6-12 inches
P_2O_5 . . . . pounds per acre . .	42	27
pH	4.94	5.01
Calcium me. per 100 gm. of soil . .	2.4	2.4
Magnesium . . . . do	.8	1.0
Potassium . . . . do	.1	.1
Sodium . . . . do	.1	.1
Hydrogen . . . . do	11.4	10.6
Base saturation . . . . . . percent . .	22	24

The low-lime plots received 1 1/2 tons of dolomitic limestone per acre applied before seeding; the high-lime plots received 2 3/4 tons per acre before seeding and an additional ton in the spring of 1952.

The seven forage mixtures were: 1) orchardgrass (Dactylis glomerata L.) and ladino clover (Trifolium repens L. 'Ladino'); 2) a complex mixture composed of orchardgrass, smooth brome (Bromus inermis Leyss.), tall fescue (Festuca arundinacea Schreb.), timothy (Phleum pratense L.), red clover (Trifolium pratense L.), ladino clover, Kentucky bluegrass (Poa pratensis L.) and birdsfoot trefoil (Lotus corniculatus L.); 3) orchardgrass, tall fescue and ladino clover; 4) smooth brome and alfalfa (Medicago sativa L.); 5) Kentucky bluegrass and ladino clover; 6) orchardgrass and birdsfoot trefoil; and 7) tall fescue and ladino clover.

The fertilizer treatments consisted of rates and ratios of phosphorus and potassium as follows (applied annually except where indicated otherwise): 1) 300 pounds K_2O per acre, 2) 50 pounds P_2O_5 + 100 pounds K_2O, 3) 50 pounds P_2O_5 + 300 pounds K_2O, 4) 150 pounds P_2O_5, 5) 150 pounds P_2O_5 + 100 pounds K_2O, 6) 150 pounds P_2O_5 + 300 pounds K_2O, 7) 150 pounds P_2O_5 + 100 pounds K_2O (applied the first year only), and 8) 300 pounds P_2O_5 + 300 pounds K_2O (applied the first year only). Fertilizer was applied in March, beginning in 1951.

Plant stands were determined in 1951 by the point-quadrat method after the plots were well established. These data indicated that in all mixtures the stands were adequate and uniform and that the balance of grass to legumes was at a level considered good.

In 1952 one harvest was made on the low-lime plots of smooth brome and alfalfa mixture. Three harvests were made on both lime levels of all the other mixtures. The smooth brome-alfalfa plots under low lime were so poor in 1953 and 1954 that yields were not recorded. Three harvests per year were obtained from all other treatments.

A power mower equipped with a 3-foot sickle bar was used in harvesting. At the time of harvest a 1 1/2-foot border was cut from each end of the plot. A 3-foot swath was then cut through the center of the plot for yields. After the harvested sample was weighed for yield, a representative subsample was drawn from each plot for dry-matter and botanical and chemical determinations. These samples were dried in a forced-air dryer at a temperature of 180° F. for 48 hours. Chemical analyses included crude-protein determination and spectrographic analysis for both the major and minor elements, P, Ca, Mg, Na, B, Al, Fe, Mn, and Cu. Potassium was determined by means of the flame photometer. Botanical composition was determined by estimation of the dry sample by two or three technicians. Occasional hand separation of samples was used to check and maintain the accuracy of estimates. The forage yield and botanical composition data were statistically analyzed and mean comparisons made with the Duncan's multiple range test (11)[4].

FORAGE YIELDS

The maintenance of yields and the balance of species in forage mixtures depend on mineral nutrition of the plants, properly coordinated with other factors of management and production. Many studies in the Northeastern States have shown potassium to be the most limiting single element for production and maintenance of legumes and grass-legume mixtures. Most forage mixtures have shown less response to phosphorus on many soils.

Review of Literature

Parsons, Drake, and Colby (25) found increases of 30 to 80 percent in hay production when adequate potassium was applied to ladino clover, orchardgrass, smooth brome, and timothy. Several applications of potassium were found to be almost completely removed (79 to 94 percent) in 3 crop years. They (25) pointed out that it would not be possible to build up reserves of soil potassium while producing large yields of forage on these soils. Their studies also showed that, although percentage of phosphorus in the plant material increased with added increments of phosphorus, there was no appreciable increase above the lowest rate. They further indicated that phosphate needs could be met for 3 to 4 years by application of 50 to 100 pounds per acre at seeding.

Several studies in the Northeast and Midwest (13, 39) have indicated that potassium is the most important element in maintaining high yield and persistence of alfalfa. Bear and Prince (1) found that where all fertilizer was applied before seeding, alfalfa accumulated large amounts of potassium in the first few crops with a resultant depletion of this element from most soils. Hanway and coworkers (16) found that on a very potassium deficient soil in Iowa as high as 100 percent of the applied potassium was recovered in the forage from an alfalfa-timothy meadow. Soil tests at the end of the experiment indicated a considerable increase in available phosphorus in the surface layer from applications of 120 or more pounds per acre of phosphate. Residual potash could not be detected by soil tests.

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[4] Underscored numbers in parentheses refer to Literature Cited, p.31

Stivers and Ohlrogge (34) found no yield response to applied phosphate where soil level of P_2O_5 was 98 pounds per acre but did find response where soil level of P_2O_5 was 34 pounds. They found stand maintenance of alfalfa closely related to potash fertilization and the potassium composition of the plant. Gerwig and Ahlgren (13) found in New Jersey that phosphorus had no significant beneficial effect on yield of alfalfa. An increase in yield was obtained with each increment of K_2O applied up to 200 pounds per acre. Stand was decreased by as much as 80 percent on those plots not receiving potash.

Since the completion of these studies, Brown (6) has reported on studies on a ladino clover and orchardgrass mixture on a potassium deficient soil in Connecticut. He found that stands of clover and yields of dry matter were maintained much better by relatively small applications of KCl, applied frequently, than by less frequent heavier dosages. Greater efficiency was obtained by applying one-fourth of the KCl after each harvest. This type of application minimizes the possibility of luxury consumption of potassium by the forage plants.

Results and Discussion

The tabulated data given represent the total annual production of weed-free dry matter per acre harvested in three cuttings. Some of the mixtures such as orchardgrass and ladino clover; tall fescue and ladino clover; orchardgrass, tall fescue, and ladino clover; and the complex mixture responded similarly to fertilizers. The data from some of these mixtures will be discussed in detail.

The relative yields of the various forage mixtures changed considerably from year to year. Fertilizer effects during the 1952 season were less striking than later. Orchardgrass and ladino clover (table 2); the complex mixture (table 3); and orchardgrass, tall fescue, and ladino clover (table 4) were the higher yielding mixtures in comparable treatments during this first year. The dominant species in all these mixtures in 1952 were orchardgrass and ladino clover.

These three higher yielding mixtures produced approximately 4 tons of dry matter on the high-potassium plots in 1952. Kentucky bluegrass and ladino clover (table 5) was the only mixture that showed a significant yield response from the use of phosphorus alone in the first year. The application of 150 pounds of P_2O_5 alone produced the highest yield of bluegrass and ladino clover mixture on both lime levels that year.

Smooth brome and alfalfa (table 6) was one of the lowest producing mixtures during the first season. Although this mixture produced approximately 3 tons of dry matter under high-lime and high-potassium treatments, the

Table 2.--Effects of phosphorus and potassium rates and ratios and lime levels on yield of weed-free dry matter from an orchardgrass and ladino clover mixture

Fertilizer rate (pounds per acre)		Yield, per acre, of weed-free dry matter at--							
		High-lime level				Low-lime level			
P_2O_5	K_2O	1952	1953	1954	Average[1]	1952	1953	1954	Average[1]
		Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
0	300	3.48	3.01	2.29	2.93 c	3.11	2.71	2.14	2.65 d
50	100	3.67	3.00	2.39	3.02 c	3.34	2.77	2.29	2.80 c
50	300	3.92	3.31	2.87	3.37 b	3.47	3.03	2.54	3.01 b
150	0	3.43	2.67	1.87	2.66 e	3.33	2.34	1.74	2.47 e
150	100	3.81	3.32	2.66	3.26 b	3.42	3.02	2.47	2.97 b
150	300	4.12	3.80	3.03	3.65 a	3.64	3.26	2.62	3.17 a
150 [2]	100 [2]	3.55	2.71	1.99	2.75 de	3.07	2.33	1.79	2.40 e
300 [2]	300 [2]	4.01	2.73	1.99	2.91 cd	2.97	2.38	1.89	2.41 e
Average					3.07 a				2.74 b

[1] Differences between 3-year averages of fertilizer treatments within a lime level and between lime level averages followed by the same letter or letters are not significant at the 5-percent level.

[2] Applied the first year only.

Table 3.--Effects of phosphorus and potassium rates and ratios and lime levels on yield of weed-free dry matter from a complex forage mixture[1]

Fertilizer rate (pounds per acre)		Yield, per acre, of weed-free dry matter at--							
		High-lime level				Low-lime level			
P_2O_5	K_2O	1952	1953	1954	Average[2]	1952	1953	1954	Average[2]
		Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
0	300	3.61	2.66	2.38	2.88 c	2.83	2.69	1.96	2.49 de
50	100	3.79	2.84	2.74	3.12 ab	3.14	2.89	2.39	2.81 c
50	300	3.77	2.87	2.82	3.15 ab	3.09	3.04	2.36	2.83 bc
150	0	3.34	2.46	1.84	2.55 e	2.99	2.71	1.89	2.53 de
150	100	3.85	3.06	2.73	3.21 a	3.19	3.12	2.48	2.93 b
150	300	3.78	2.89	2.49	3.05 b	3.45	3.40	2.81	3.22 a
150 [3]	100 [3]	3.46	2.46	2.12	2.68 de	2.99	2.43	1.90	2.44 e
150 [3]	300 [3]	3.57	2.58	2.02	2.72 d	3.06	2.79	2.05	2.63 d
Average					2.92 a				2.74 a

[1] Composed of orchardgrass, smooth brome, tall fescue, timothy, red clover, ladino clover, Kentucky bluegrass, and birdsfoot trefoil.

[2] Differences between 3-year averages of fertilizer treatments within a lime level and between lime level averages followed by the same letter or letters are not significant at the 5-percent level.

[3] Applied the first year only.

Table 4.--Effects of phosphorus and potassium rates and ratios and lime levels on yield of weed-free dry matter from an orchardgrass, tall fescue, and ladino clover mixture

Fertilizer rate (pounds per acre)		Yield, per acre, of weed-free dry matter at--							
		High-lime level				Low-lime level			
P_2O_5	K_2O	1952	1953	1954	Average 1/	1952	1953	1954	Average 1/
		Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
0	300	3.41	2.83	2.22	2.82 bc	3.03	2.71	2.00	2.58 d
50	100	3.37	2.81	2.13	2.77 bc	3.22	2.68	2.33	2.74 c
50	300	3.39	2.94	2.34	2.89 b	3.33	3.19	2.18	2.90 b
150	0	3.23	1.91	1.16	2.10 e	3.26	2.34	1.66	2.42 e
150	100	3.64	2.84	2.11	2.86 bc	3.82	2.89	2.25	2.99 b
150	300	3.95	3.22	2.49	3.22 a	3.73	3.13	2.60	3.15 a
150 2/	100 2/	3.36	2.17	1.47	2.33 d	3.18	2.56	1.72	2.49 de
300 2/	300 2/	3.78	2.53	1.82	2.71 c	3.70	2.53	2.01	2.75 c
Average					2.72 a				2.75 a

1/ Differences between 3-year averages of fertilizer treatments within a lime level and between lime level averages followed by the same letter or letters are not significant at the 5-percent level.

2/ Applied the first year only.

Table 5.--Effects of phosphorus and potassium rates and ratios and lime levels on yield of weed-free dry matter from a Kentucky bluegrass and ladino clover mixture

Fertilizer rate (pounds per acre)		Yield, per acre, of weed-free dry matter at--							
		High-lime level				Low-lime level			
P_2O_5	K_2O	1952	1953	1954	Average 1/	1952	1953	1954	Average 1/
		Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
0	300	2.76	2.32	2.39	2.49 bc	2.38	2.09	1.08	1.85 e
50	100	2.82	2.34	2.49	2.55 ab	2.53	2.19	1.90	2.21 ab
50	300	2.88	2.62	2.54	2.68 a	2.40	2.17	1.71	2.09 b-d
150	0	3.41	2.43	1.38	2.41 bc	2.68	2.25	2.01	2.31 a
150	100	3.03	2.58	2.47	2.69 a	2.56	1.90	1.80	2.09 b-d
150	300	2.85	2.16	2.32	2.44 bc	2.56	2.24	1.69	2.16 a-d
150 2/	100 2/	3.21	2.39	1.55	2.38 c	2.29	2.01	1.77	2.02 d
300 2/	300 2/	3.17	2.44	2.02	2.54 ab	2.37	2.05	1.71	2.04 cd
Average					2.52 a				2.10 b

1/ Differences between 3-year averages of fertilizer treatments within a lime level and between lime level averages followed by the same letter or letters are not significant at the 5-percent level.

2/ Applied the first year only.

yield was significantly lower than that from the mixtures containing ladino clover with comparable treatments. Smooth brome and alfalfa mixture showed a greater response to fertilizer treatments in the first season than any of the other mixtures. The dry-matter yield of plots that received 100 pounds of K_2O per acre was about 1/2 ton per acre more than that of the plots that received only phosphorus, and the increase from 300 pounds K_2O was nearly 1 ton per acre. The addition of more than 50 pounds per acre of phosphorus had very little effect on yield.

Table 6.--Effects of phosphorus and potassium rates and ratios on yield of weed-free dry matter from smooth brome and alfalfa mixture

Fertilizer rate (pounds per acre)		Yield, per acre, of weed-free dry matter at high-lime level			
P_2O_5	K_2O	1952	1953	1954	Average[1]
		Tons	Tons	Tons	Tons
0	300	2.67	3.61	3.22	3.17 c
50	100	2.82	3.44	3.82	3.36 b
50	300	3.10	3.63	4.03	3.59 a
150	0	2.18	1.13	1.99	1.77 f
150	100	2.74	3.24	3.73	3.24 bc
150	300	3.07	3.43	4.08	3.53 a
150 [2]	100 [2]	2.63	2.04	2.14	2.27 e
300 [2]	300 [2]	3.00	2.26	2.26	2.51 d
Average					2.93

[1] Differences between 3-year averages of fertilizer treatments within a lime level and between lime level averages followed by the same letter or letters are not significant at the 5-percent level.

[2] Applied the first year only.

In 1953 smooth brome and alfalfa was the highest yielding mixture on high-potash and high-lime plots. Yields on these plots increased significantly over the 1952 yields; however, there was a comparable decrease in the low-potash treatments. Average yields on all plots indicated that smooth brome and alfalfa was the only mixture that did not have an over-all decrease during the second year. The response of the Kentucky bluegrass and ladino clover to phosphorus decreased during the second year and was negative in the third year. Botanical-composition data indicate that the legume component of the mixture decreased each year under low-potash treatments; therefore, by the third year, the lack of legumes in these plots was reflected in the yield reduction. The orchardgrass and birdsfoot trefoil mixture (table 7) at the high-lime level had the greatest yield decrease in 1953.

The data for the 1954 season indicate that yield of all mixtures except smooth brome and alfalfa on high lime and orchardgrass and birdsfoot trefoil on low lime had declined considerably. A drop in ladino clover content, especially with the poorer treatments, probably accounted for much of the yield decline (tables 2-5, 8). Response of most of the mixtures to potassium and lime level, however, became even more striking despite the over-all decline in yield.

On plots receiving 300 pounds per acre of K_2O, smooth brome and alfalfa mixture yielded approximately 4 tons of weed-free dry matter in 1954 as compared with approximately 2 to 2 3/4 tons from many of the other mixtures. Smooth brome and alfalfa mixture receiving P_2O_5 alone annually or P_2O_5 and K_2O applied only in the first year yielded approximately 2 tons per acre in 1954, or about half the production of that receiving the high rate of potassium.

For smooth brome and alfalfa mixture, the plot to which 300 pounds per acre of K_2O and P_2O_5 had been applied in 1951 only was the highest yielding one in the first cutting of 1952. Thereafter, it declined rather rapidly, and by the fall of 1952 the alfalfa was showing potash-deficiency symptoms. In 1953 this treatment produced about 1 ton more than the no-potash treatment but usually more than a ton under those that received either 100 or 300 pounds per acre of K_2O each year. By 1954 the yield of the plots receiving 300 pounds of K_2O and 300 pounds of P_2O_5 the first year only had dropped to almost the level of the no-potash plot. About the same trend was evident in plots on which 150 pounds P_2O_5 and 100 pounds K_2O were applied the first year only except for even less residual effect. However, the difference between the two treatments was not so great as might have been expected.

Highest yields in most instances were maintained where 300 pounds per acre of K_2O were applied each year at the high-lime level. The best smooth brome and alfalfa plots produced over 4 tons of dry matter per acre in the last year of the study. At high-lime level, with some of the mixtures, such as the Kentucky bluegrass and ladino clover and the orchardgrass and birdsfoot trefoil, 100 pounds per acre of potash was nearly as effective as 300 pounds. However, often where only 100 pounds of K_2O was applied, the alfalfa and clover showed deficiency symptoms in the last cutting of each year. Although this rate appeared to have little effect on forage stands during the 2- to 3-year period of the experiment, it did reduce yields considerably. This, together with similar results elsewhere, suggests that about 200 pounds per acre of K_2O each year would be more realistic than either the higher or the lower rates for the brome and alfalfa mixture and the higher yielding mixtures with ladino clover.

The influence of lime level was evident on most of the mixtures and pronounced on some. These effects were most noticeable during the last year of the study, although at the low-lime level most of the alfalfa plants were eliminated during the seedling year.

Table 7.--Effects of phosphorus and potassium rates and ratios and lime levels on yield of weed-free dry matter from an orchardgrass and birdsfoot trefoil mixture

Fertilizer rate (pounds per acre)		Yield, per acre, of weed-free dry matter at--							
		High-lime level				Low-lime level			
P_2O_5	K_2O	1952	1953	1954	Average[1]	1952	1953	1954	Average[1]
		Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
0	300	2.93	1.86	2.33	2.37 b	2.68	2.34	2.85	2.62 bc
50	100	3.11	1.90	2.25	2.42 b	3.12	2.58	2.95	2.88 a
50	300	3.29	2.05	2.47	2.60 a	2.63	2.49	2.99	2.70 bc
150	0	3.10	1.54	1.53	2.06 c	3.06	1.66	2.05	2.26 d
150	100	3.29	2.10	2.03	2.57 ab	3.11	2.40	2.80	2.77 ab
150	300	3.33	1.69	2.07	2.36 b	2.91	2.17	2.79	2.62 bc
150 [2]	100 [2]	3.07	1.45	1.67	2.06 c	2.85	1.90	2.35	2.37 d
300 [2]	300 [2]	3.26	1.48	1.49	2.08 c	2.93	2.26	2.56	2.58 c
Average					2.30 b	. . . .			2.60 a

[1] Differences between 3-year averages of fertilizer treatments within a lime level and between lime level averages followed by the same letter or letters are not significant at the 5-percent level.

[2] Applied the first year only.

Table 8.--Effects of phosphorus and potassium rates and ratios and lime levels on yield of weed-free dry matter from a tall fescue and ladino clover mixture

Fertilizer rate (pounds per acre)		Yield, per acre, of weed-free dry matter at--							
		High-lime level				Low-lime level			
P_2O_5	K_2O	1952	1953	1954	Average[1]	1952	1953	1954	Average[1]
		Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
0	300	2.45	2.54	2.48	2.49 b	2.47	2.16	1.68	2.10 b
50	100	2.43	2.56	2.52	2.50 b	2.44	2.32	1.98	2.25 a
50	300	3.16	2.41	2.74	2.77 a	2.70	2.32	2.07	2.36 a
150	0	2.58	2.52	2.04	2.38 b	2.30	1.91	1.47	1.89 c
150	100	2.91	2.53	2.52	2.65 a	2.53	2.52	1.95	2.33 a
150	300	2.86	2.52	2.66	2.68 a	2.66	2.33	2.04	2.34 a
150 [2]	100 [2]	2.95	2.40	1.91	2.42 b	2.40	1.99	1.55	1.98 bc
300 [2]	300 [2]	2.88	2.27	2.00	2.38 b	2.41	2.54	1.79	2.25 a
Average					2.54 a	. . . .			2.19 b

[1] Differences between 3-year averages of fertilizer treatments within a lime level and between lime level averages followed by the same letter or letters are not significant at the 5-percent level.

[2] Applied the first year only.

Contrary to what might be expected, the orchardgrass and birdsfoot trefoil plots on low lime, fertilized with high rates of potassium, yielded 3/4 to 1 ton more than comparable plots on high lime in 1954. Reversals of this kind were also noted on some of the plots of the orchardgrass, tall, fescue, and ladino clover mixture and the complex mixture in 1953 and 1954 as well as on the low-potash plots of bluegrass and ladino in 1954. The consistent superiority of the low-lime treatments of the orchardgrass and birdsfoot trefoil mixture at all fertility levels during both 1953 and 1954 is difficult to explain. The data on botanical composition indicate a consistent increase in the percentage of trefoil in the mixture at the low-lime level. Although orchardgrass does well at fairly low-lime levels, it may not have been so competitive with the trefoil under these conditions.

Summary

The effect of rates and ratios of phosphorus and potassium fertilizers and lime levels on forage yield of seven grass-legume mixtures was studied over a 3-year period. The most striking response was to potash fertilizer. In most of the forage mixtures the addition of 100 or 300 pounds of K_2O per acre was necessary to maintain top yields. In general, yields varied with the amount of legume in the mixtures.

Smooth brome and alfalfa showed the most outstanding response to potassium. Highest yields were obtained with annual applications of 300 pounds of K_2O per acre. Application of high rates of potassium (300 pounds of K_2O per acre) at seeding was not sufficient to maintain top forage yields in most of the mixtures beyond the first cutting the year after application. High rates of potash applied the first year only gave only a slight residual effect the year after application in most mixtures. All legumes in those treatments receiving less than 100 pounds of K_2O per acre each year showed severe symptoms of potassium deficiency at the end of the second year. Even some of the plots to which 100 pounds of K_2O were applied each spring showed potash-deficiency symptoms in the fall of each year.

Greatest response to phosphorus was obtained with Kentucky bluegrass and ladino clover mixture in the first year. Orchardgrass and ladino clover mixture also responded to the higher rate of phosphorus. Usually, however, phosphate needs appeared to be satisfied with application of 150 pounds of P_2O_5 per acre at seeding or about 50 pounds per acre annually.

Lime was a limiting factor in the production of the smooth brome and alfalfa mixture. Alfalfa was almost completely eliminated from all low-lime plots before the first harvest season began. The other mixtures except the orchardgrass and birdsfoot trefoil, the orchardgrass, tall fescue, and ladino clover, and the complex mixture were also more productive at the high-lime level, particularly where adequate potash was applied. Orchardgrass and birdsfoot trefoil was the only mixture for which the data indicate a consistent reverse response. In the second year of the study all fertilizer treatments with the orchardgrass and birdsfoot trefoil mixture on low lime except the one receiving P_2O_5 alone were significantly higher than comparable treatments under high lime. This relation was even more striking in the third.

The balance of legumes and grasses changed considerably during the 3 years of the study. The plots that received a high annual application of potash maintained the percentage of legumes at a fairly good level. The percentage of legumes in the low-potash plots and in those plots fertilized at seeding only began decreasing after the first year. This decrease continued until only a small component of legume remained. Yields decreased in general as the proportion of legumes decreased.

BOTANICAL COMPOSITION OF HARVESTED FORAGE

The difficulty of maintaining adequate legume stands in forage mixtures is one of the major problems in hay and pasture production. In many regions especially in the Northeast, this has been considered one of the principal causes of decreasing yields.

The problem of maintaining adequate legume stands in grass-legume mixtures is influenced by several factors. Disease and insects play important parts in the persistence of ladino clover in the Northeast (21). Competition between the legume and its companion grass for nutrients, light, and water is most important in legume persistence. At least part of this competition can be overcome with improved grazing and clipping management practices and adequate fertilization.

Review of Literature

Legumes are a very important component of most pasture and hay crops. Their importance to forage quality and yield has been illustrated repeatedly in experiments in most regions. The problem of legume-stand depletion, therefore, has received considerable attention recently.

Studies in several regions and on various soil types have indicated that the nutrient level of the soil is one of the major factors affecting legume persistence. In most of these studies potassium caused the greatest growth and persistence of legumes. Sprague and Eby (33) found that after 6 years only about one-third as much ladino clover remained in Kentucky bluegrass where no potassium was added as where 200 pounds of K_2O was applied per acre. Parsons, Drake, and Colby (25) in Massachusetts reported that, from low-potash plots, ladino clover in the harvested forage decreased from 90 percent at the end of the first crop year to 45 percent in the spring of the second year; by the end of that year it had decreased to 15 percent; by the spring of the third year it had decreased to 5 percent. From high-potash plots, ladino clover decreased from over 90 percent at the end of the first crop year to 81 percent in the spring of the second year; by the end of that year it had decreased to 68 percent; by the spring of the third year it had decreased to 30 percent.

Results of studies on Connecticut (7) and New York (8) soils indicated that longevity of alfalfa stands was increased greatly by potash fertilizers on soils originally low in potassium. Stivers and Ohlrogge (34) in fertilizer studies with alfalfa on two Indiana soils found potassium to give large yield responses. Stand maintenance of alfalfa was closely related to potassium fertilization.

Rich and Odland (26) found potash to have a very pronounced effect on both yield and the percentage of legume in the mixture. When the potash level was reduced from 100 to 50 pounds the proportion of legumes was lowered from 50 to 3 percent and hay yield from 3.08 to 1.63 tons per acre. Results of experiments on the Black Belt soils of Alabama (28) indicated that, after establishment, phosphorus produces good clover growth on all but the high-lime soils. Continued applications of phosphorus alone, however, create potassium deficiencies as a result of forage removal. Competition between the clovers and grasses for the available potassium usually results in a loss of the clover stands.

The unfavorable competition between grasses and legumes for potassium is well illustrated by the work of Blaser and Brady (3). Their work indicates that the growth of grasses in mixture with legumes is stimulated and the amount of potassium removed by the grasses is increased by nitrogen fertilization. Therefore, the effect of nitrogen on reducing the legume component was attributed to competition for potassium.

The difference in the cation-exchange capacity of roots has been suggested as a factor in the differential uptake of plant nutrients. Drake, Vengris, and Colby (10) found that dicots have roughly double the cation-exchange capacity of monocots. They proposed this as a partial explanation of why grasses are able to obtain more potassium than legumes when growing in association at low-potassium levels. Results of studies by Gray, Drake, and Colby (14) indicated that potassium uptake by individual plant species at low levels of potassium was well correlated with root cation-exchange capacity but at high levels of soil potassium differences in feeding power for potassium were reduced. Results of studies by Parsons, Drake, and Colby (25) indicate that grass is better able to survive than clover at low levels of soil potassium. Where 300 pounds of K_2O per acre was applied, ladino clover removed 157 pounds per acre whereas orchardgrass removed 298 pounds.

Results and Discussion

The botanical-composition data are of interest largely because they indicate the effect of fertilization on the persistence of the legume component of the mixture. The data for 1954 should, therefore, be sufficient to show the persistence of the legume after 3 years. Some discussion of trends in other years are presented, but tabulation is omitted. Since it has been indicated that variation in legume component was largely due to potassium fertilization, the treatments discussed include the three levels of potassium at only one level of phosphorus.

Some of the mixtures contained a slightly higher legume percentage in the second cutting than in the first cutting, but the percentage declined sharply at the third cutting in each of the 3 years. The exceptions were the orchardgrass and birdsfoot trefoil and the brome and alfalfa mixtures (table 9). The legume components of these mixtures increased each successive

Table 9.--Effects of potassium fertilizer and lime levels on percentage legume in the harvested forage from various legume-grass mixtures, 1954

[150 pounds per acre of P_2O_5 were applied to each plot]

K_2O, pounds per acre	Percentage legume in harvested forage at--							
	High-lime level				Low-lime level			
	First cut	Second cut	Third cut	Average[1]	First cut	Second cut	Third cut	Average[1]
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Orchardgrass and Birdsfoot Trefoil Mixture								
0	9	17	42	23 b	17	26	39	27 b
100	13	25	52	30 a	40	42	52	45 a
300	7	24	33	21 b	32	43	62	46 a
Smooth Brome and Alfalfa Mixture								
0	63	67	88	73 c	--	--	--	--
100	62	91	98	84 b	--	--	--	--
300	74	97	99	90 a	--	--	--	--
Orchardgrass and Ladino Clover Mixture								
0	1	10	10	7 b	1	5	3	3 b
100	3	22	9	11 ab	2	13	4	23 a
300	3	18	16	12 a	2	19	10	19 a
Kentucky Bluegrass and Ladino Clover Mixture								
0	2	8	9	6 c	6	9	20	12 b
100	38	22	43	34 b	27	25	18	23 a
300	45	40	48	44 a	23	18	17	19 a
Tall Fescue and Ladino Clover Mixture								
0	8	12	4	8 b	5	17	4	9 b
100	18	37	16	24 a	21	28	13	21 a
300	27	38	18	28 a	23	27	19	23 a
Complex Mixture[2]								
0	2	11	3	5 b	2	11	6	6 a
100	2	14	18	11 a	3	16	5	8 a
300	8	28	19	18 a	4	12	9	8 a

[1] Means relating to one mixture and the same lime level followed by the same letter or letters do not differ significantly at the 5-percent level.

[2] Composed of orchardgrass, smooth brome, tall fescue, timothy, red clover, ladino clover, Kentucky bluegrass, and birdsfoot trefoil.

cutting during the season. This consistent increase in legume percentage at the second cutting was probably due to differential seasonal growth of the companion grass. The first cutting is generally made when most grasses especially orchardgrass, have reached the peak of spring growth. The increased growth of grass would lower the legume percentage even if the total yield of legume remained constant. In addition, total forage yields are usually higher at the first harvest.

The 1953 data indicate that in that year the legume component of the harvested forage was more evenly distributed over the three cuttings than it was in other years. The characteristic peak at the second cutting was still evident but to a lesser extent. Legume percentage appeared to have reached a peak in 1953. The late-spring and early-summer precipitation in 1953, which was above average for that period, probably stimulated ladino clover production. First-cutting clover percentages were unusually high in 1953.

The increase in legume component due to potash was very striking in 1953. At the high-lime level, for example, the bluegrass and clover mixture contained clover percentages of 27, 22, and 37 in the first, second, and third cuttings, respectively, at low-potash levels. The same cuttings at high-potash levels contained 67, 64, and 61 percent ladino clover, respectively. Total legume production averaged 1,200, 1,440, and 680 pounds per acre at high-potash levels and 540, 520, and 280 pounds per acre at low-potash levels in the first, second, and third cuttings, respectively. The differences due to potash were almost as striking in all the forage mixtures. The legume component in the smooth brome and alfalfa mixture averaged about 50 percent on low-potash plots and approximately 80 percent on high-potash plots. The total legume yield averaged 1,680 and 6,480 pounds per acre on the low- and high-potash plots, respectively.

Legume percentages in the harvested forage were reduced considerably in all mixtures containing ladino clover during 1954. The legume component in birdsfoot trefoil and alfalfa mixtures, however, was increased significantly, particularly under high-potash treatments, when compared with the previous years.

Differences in legume composition of the harvested forage resulting from potash fertilization were probably as striking in 1954 as in 1953, although, generally, legume percentages were somewhat lower. Although a general decline in percentage of ladino clover was evident, the high-potash treatments still contained enough ladino clover to be considered a desirable mixture.

Some of the reduction in ladino production in 1954 may be attributed to lack of precipitation. The precipitation during the 1952 and early 1953 growing seasons was somewhat above normal. Precipitation in 1954 was considerably below normal, and its distribution was poor.

The ladino clover percentage in the orchardgrass and ladino clover mixture at high-lime level was 5 percent higher in the high-potash plots than in the low-potash plots (table 9); at the low-lime level it was 7 percent higher in the high-potash plots. This represents increases in total legume yield of 177 and 390 percent from potash application at the high- and low-lime levels, respectively. The bluegrass and ladino clover mixture at the high-lime level (table 9) averaged 38 percent more ladino clover with the high rate of potash than with the low rate, and a total legume yield increase of 1,876 pounds per acre. At the low-lime level there was an increase in ladino clover of only 7 percent as a result of high-potash application, with an increase of only 270 pounds per acre in total legume yield. Ladino clover generally showed more response to potassium fertilizer when grown with tall fescue than when grown with any of the other grasses (table 9). The legume percentage in comparable treatments was somewhat lower in the orchardgrass and ladino and complex mixtures (table 9) than in others. The change in botanical composition brought about by inadequate potash fertilization is illustrated in figures 1 and 2.

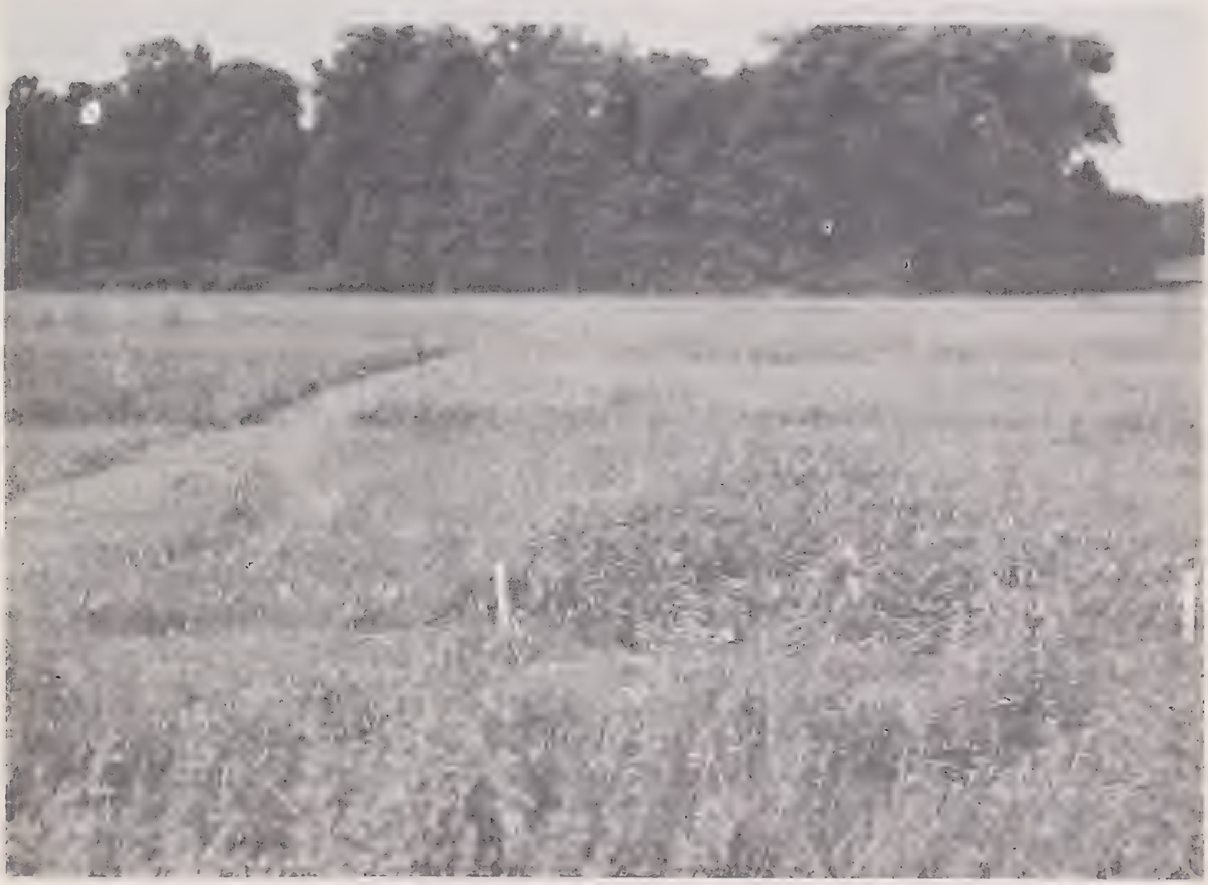

Figure 1.--Bluegrass and ladino clover mixture at high rate of lime, 1954; left, 150 pounds of P_2O_5 without potash each year; right, 300 pounds of K_2O without phosphorus each year.

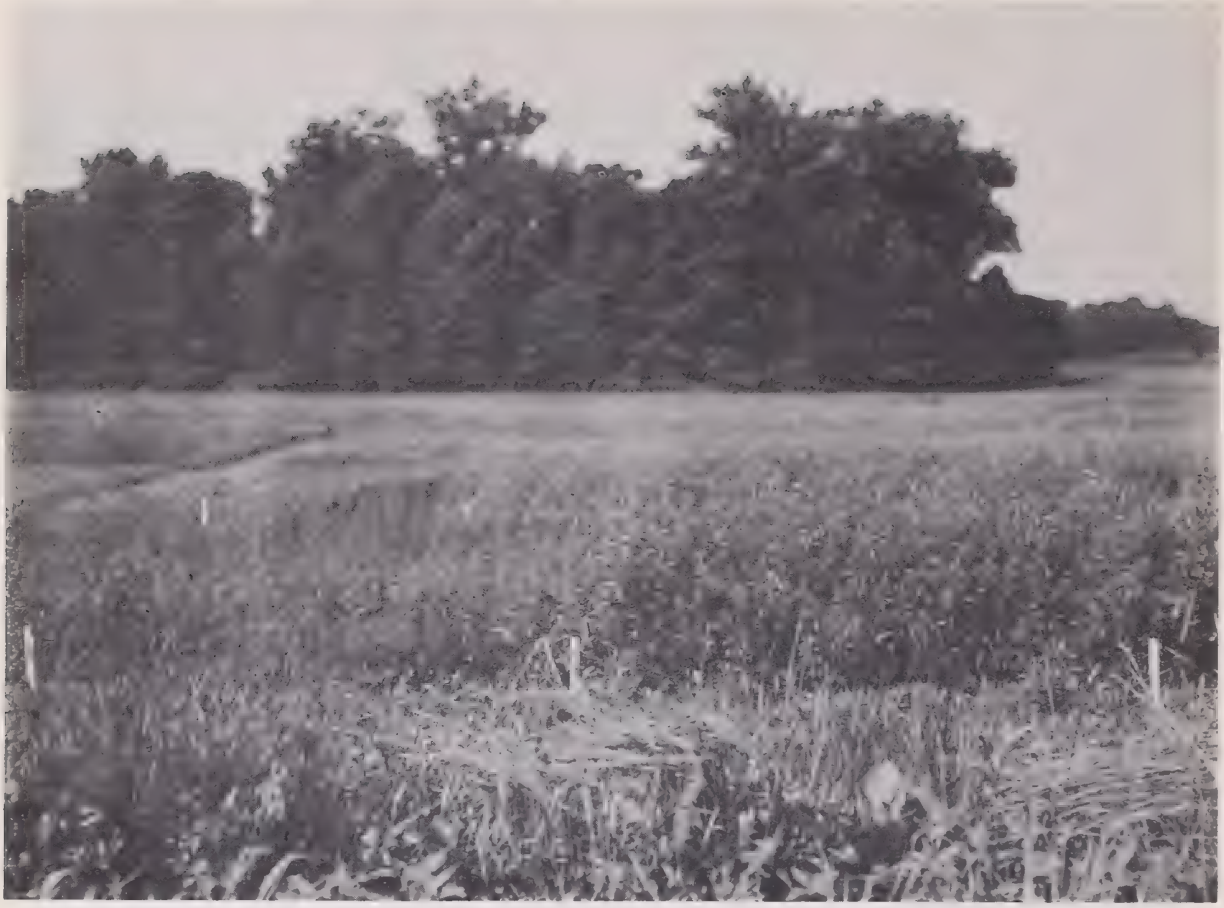

Figure 2.--Smooth brome and alfalfa mixture at high rate of lime, 1954; left, 150 pounds of P_2O_5 without potash each year; right, 300 pounds of K_2O without phosphorus each year.

Lime level had very little effect on botanical composition in the first season on mixtures containing ladino clover except for the mixture containing bluegrass. Plots containing bluegrass were considerably higher in clover at low-lime levels than comparable plots at high-lime levels. This relation was true to a lesser extent in 1953 but was reversed in 1954.

The legume component in the orchardgrass and birdsfoot trefoil mixture was higher at the low-lime level than at the high-lime. On the high-potash plots, the legume percentage in the low-lime plots continued to increase over the high-lime plots throughout the study. In 1954, with high-potash application, the low-lime plots contained approximately 100 percent more legumes than comparable high-lime plots. The advantage shown by the birdsfoot trefoil under conditions that ordinarily would not favor legume growth is difficult to explain. Perhaps there was less competition from the orchardgrass under low-lime conditions. There was generally a higher weed population on low-lime plots, which usually indicates a lower grass population. The weeds, being possibly less competitive than the grass, permitted better growth of the legume.

Legume Composition Versus Legume Yield

Differences in the legume component due to potash treatment do not appear exceptionally large when expressed merely as a percentage of the total botanical composition. However, if this increase is expressed as a percentage increase in legume yield, it appears more significant and is actually shown in its true perspective (table 10).

In the smooth brome and alfalfa mixture, the total forage yield at the high-potash level was 105 percent over that at the no-potash level. The legume percentage of the harvested forage was only increased from 73 percent with no potash to 90 percent with high potash; however, this represents an increase in total legume yield of 153 percent over no potash. The legume component in the orchardgrass and ladino clover mixture increased from 7 percent with no potash to 12 percent with high potash. However, this represents an increase in total legume yield of 177 percent over no potash. The legume yields of the tall fescue and ladino clover and complex mixtures increased over 300 percent with the high potash rate.

Weedy Species

The data on percentage weedy species are not presented. Several significant facts, however, were evident. Population of weeds was extremely low at the first cutting in 1952 but reached a peak at the third cutting in 1952. Subsequently weedy species declined rapidly in all mixtures. Weedy species were negligible in 1954 under all treatments except for the smooth brome and alfalfa plots that received low rates of potash or potash the first year only. Of the mixtures containing ladino clover, only those with tall fescue and bluegrass contained any appreciable level of weedy species in 1953. In 1954 weeds had almost disappeared from all clover-grass mixtures until the third cutting, when they again became evident in the tall fescue and bluegrass mixtures. All mixtures contained more weeds under low lime than under high lime.

Summary

The influence of potassium fertilizers on the legume component of the forage mixtures was very striking. Some of the mixtures contained a slightly higher legume percentage in the second cutting than in the first cutting, but the percentage declined sharply at the third cutting in each of the 3 years. Most of the forage mixtures containing ladino clover reached a peak in legume percentage of the harvested forage in the second year of the test.

The increase in clover percentage from potash fertilization ranged from 30 to 40 percent in the bluegrass and ladino clover mixture, with a total legume production increase from 400 to 900 pounds per acre, in 1953. The increase in legume percentage of the smooth brome and alfalfa mixture was approximately 30 to 40 percent, with a legume yield increase of about 4,800 pounds per acre.

Table 10.--Effects of potassium on yield and botanical composition of 5 grass-legume mixtures at the high-lime level, 1954

[150 pounds per acre of P_2O_5 were applied on each plot]

Mixture	Total forage yield			Legume in harvested forage with indicated acre rates of K_2O		Total legume yield		
	Actual yield with indicated acre rates of K_2O		Increase with 300 pounds of K_2O			Actual yield with indicated acre rates of K_2O		Increase with 300 pounds of K_2O
	0	300		0	300	0	300	
	Pounds per acre	Pounds per acre	Percent	Percent	Percent	Pounds per acre	Pounds per acre	Percent
Smooth brome and alfalfa.	3,980	8,160	105	73	90	2,905	7,344	153
Orchardgrass and birdsfoot trefoil.	4,100	5,580	36	27	46	1,107	2,567	132
Orchardgrass and ladino clover.	3,740	6,060	62	7	12	262	727	177
Tall fescue and ladino clover.	4,080	5,320	30	8	28	326	1,490	357
Complex[1]	3,680	4,980	35	5	18	184	896	387

[1] Composed of orchardgrass, smooth brome, tall fescue, timothy, red clover, ladino clover, Kentucky bluegrass, and birdsfoot trefoil.

In the first season, lime level had very little effect on botanical composition of mixtures containing ladino clover except for the mixture containing bluegrass. Bluegrass mixtures at low-lime levels were much higher in clover than comparable plots at high-lime levels. This, however, was reversed by the third harvest season.

The legume component of the orchardgrass and birdsfoot trefoil mixture was higher at the low-lime level than at the high-lime. In the high-potash plots, the legume percentage in the low-lime plots continued to increase over the high-lime plots throughout the study.

Data are presented that indicate that when differences in the legume component are expressed as a percentage increase or decrease in legume yield rather than a percentage of the forage, a more realistic expression of the response is shown.

CHEMICAL COMPOSITION OF HARVESTED FORAGE

Chemical analysis of plant material can be used to great advantage in understanding some of the responses to fertilizer treatment in forage fertility experiments. The total nutrient element content, the balance of certain elements in the plant, and the rate of removal of these elements from the soil are of value in explaining the responses of forage species to various fertilizer treatments. It also helps to explain the changes in the botanical composition of forage mixtures. Certain grass-legume mixtures have been found to be more compatible in nutrient uptake than others.

Review of Literature

The value of plant analysis in accessing the needs of plants for fertilizer elements and in estimating the nutrient level of the soil has been recognized for well over a century. However, it was not until relatively recent years that a real interest was shown in this field. Macy (23) in 1936 proposed a theory of the relationship between the sufficiency of a nutrient and its percentage content in the plant as a measure of the quantitative mineral-nutrient requirements of plants. The central concept of his theory was that there is critical percentage of each nutrient in each kind of plant above which there is luxury consumption and below which there is poverty adjustment, which is almost proportional to the deficiency until a minimum percentage is reached. This concept is finding increased use in the field of forage crops fertility.

The literature on mineral content and critical nutrient levels is considerably more extensive for alfalfa than for any other forage species. Alfalfa is grown over a wide range of soil and climatic conditions even though its nutrient requirements are greater and more critical than in many less widely used species.

Stivers and Ohlrogge (34) found that stand maintenance in alfalfa was closely related to both potash fertilization and the potassium content of the alfalfa. The lower limit of potassium content found in alfalfa plants that survived without potash fertilization was 0.85 to 1.1 percent K. Bear and Prince (1) found that potassium application must be adequate to maintain the potassium content of the alfalfa plant at about 1 percent but must not be so large as to effect substitution for calcium and magnesium in functions common to all three cations in the plant. Gerwig and Ahlgren (13) found the critical percentage of potassium in alfalfa to vary from season to season. Their work indicates that this critical percentage lies somewhere between 1.42 and 1.84 percent.

Results of controlled experiments with ladino clover (36) indicated that the critical level of potassium was 0.8 percent and of phosphorus, 600 p.p.m. Gray, Drake and Colby (14) stated that data from several related experiments indicated that ladino clover should contain at least 1.5 percent potassium for best production. In red clover grown under greenhouse conditions, Tucker and Smith (35) found that approximately 1 percent potassium in the plant material was the critical lower limit for good growth response. Their data indicated that applications of potassium to the soil always increased the potassium content of the red clover plants and significantly increased the total yield of red clover for each soil type.

The compatibility among species grown together in forage mixtures greatly influences the mineral content of the individual species. Grasses have been shown to absorb soil potassium much more readily and at the expense of the companion legume (10). Blaser and coworkers (4) made plant analysis of the grasses, weeds, and clover in an association during the seedling development and after establishment. On a dry-weight basis, the grasses absorbed more potassium than weeds, and the weeds absorbed more potassium than ladino clover. Orchardgrass absorbed more potassium than Kentucky 31 fescue. They indicated that species adaptation influences potassium absorption. Gray, Drake and Colby (14) found potassium content of ladino clover highest when associated with smooth brome and lowest when associated with bentgrass with all potash treatments. When 60 pounds of K_2O were applied before planting and again after the first cutting, the third cutting of ladino clover contained 0.54, 0.95, and 1.07 percent potassium, respectively, with bentgrass, Kentucky bluegrass, and smooth brome. When 120 pounds were applied initially the corresponding figures were 0.54, 0.70, and 1.13. Spooner and Mott (32), in studies of several grasses and legumes in all combinations of mixtures, found that the differences in potassium content of the plant tissue were greatest at low levels of potash and were reduced to a minimum at high levels. Their studies indicated differential uptake and competition for potassium among the various species and combinations.

Results of several studies have indicated that the recovery of applied potassium in forage crops is extremely high on most soils. Hanway and coworkers (16) indicated that the apparent recovery of applied potash was as high as 100 percent from several treatments on an alfalfa-timothy meadow on a potash-deficient soil. In more recent studies Robinson and coworkers (27) calculated the recovery of potassium fertilizer in the herbage from 86 to 95 percent. An additional 6 to 15 percent showed up as residual exchangeable potassium in the soil. This accounted for 94 to 110 percent of the applied potassium. The calculated potassium recovery for all treatments averaged 99.6 percent.

Time of application of fertilizer, especially potassium, to forage crops has received considerable attention in recent years. It would be reasonable to expect that split applications of potassium, by minimizing luxury consumption and leaching, would be more efficient than one annual application. Variation in the findings of many of these experiments indicates that several factors are involved in the response to time of application. Bear and Wallace (2) found that early spring applications of P_2O_5 and K_2O were more effective than application after removal of the first crop. In research reported since the completion of the present studies, Kresge and Younts (22) stated that most efficient use of potash fertilizer and maximum yield was made when half the fertilizer was applied in the spring and half after the first cutting. A high percentage potassium recovery coupled with a near optimum seasonal distribution was their explanation for this efficiency.

Robinson and coworkers (27) found that potassium content of orchardgrass was much higher in spring than in summer or fall. This trend was aggravated by the application of 50 pounds of K_2O either in early spring or late fall. Summer applications, however, were relatively effective in maintaining a uniform level of potassium in the herbage. Application of 100 pounds per year of K_2O even though applied in the spring, maintained the potassium content of the herbage between 2.03 and 3.22 percent. The same total amount of potash in three applications per year maintained the potassium content of the herbage between 2.23 and 3.07 percent. Nelson and MacGregor (24) indicated that spring fertilization significantly increased yields over fall treatment in only one of eight treatments.

Some workers have suggested that initial applications of phosphorus can supply forage needs over extended periods (1, 15). The critical percentage of phosphorus in forages has been found to be considerably lower than potassium (0.20 to 0.30 percent (2, 24). Hanway and coworkers (16) found very efficient recovery of the applied phosphate on soil low in available phosphorus. Variations in percentage of phosphorus in the plants due to treatment range from 0.15 to 0.37 in alfalfa and 0.12 to 0.28 in timothy.

Results and Discussion

Forage samples that were taken from the fertilizer plots at the time of harvest for dry-matter and botanical-composition determinations were used for the chemical-composition studies. The samples were completely hand separated into their grass and legume components. The spectrographic analyses were made with a large Littrow quartz (photographic) spectrograph by the total energy method and comparison standard technique. The technique used was essentailly as has been subsequently described by Specht and coworkers (31). Potassium was determined by the flame photometer.

Chemical-analysis data presented were taken from the first and second harvests of the 1952 season. Where similarity of responses were noted, only representative forage mixtures and, in some cases, representative treatments are presented in tabular form.

Potassium

The data on the percentage potassium in the harvested forage and the total potassium removed from the soil by the grass and legume components for the first two harvests are presented (table 11).

In mixtures containing ladino clover, the grasses in the first cutting contained more potassium than the associated legume except at the 300-pound annual rate of K_2O. At this rate of K_2O, the legume contained slightly more potassium than the associated grass. This indicates that the potassium was available in excessive quantity, which allowed the legume to absorb the potassium in competition with the associated grass. The grasses in the second cutting contained more potassium than the associated legume in all comparable treatments. The available potassium, even in high-potash treatments, was apparently down to a level at which competition between the grass and legume for potassium was taking place.

In the orchardgrass and ladino clover mixture at high-lime level, the potassium content of orchardgrass averaged about 3.5 percent at high level of potash application to about 2.5 percent where potash was not applied or where it was applied in 1951 only. In the comparable treatments, ladino clover averaged from 3.5 to 1.5 percent; this indicates a greater range due to treatment. The potassium content of the legume was considerably lower in the second cutting than in the first. The potassium content of the grasses was not decreased in the second cutting but usually was increased slightly.

Alfalfa and birdsfoot trefoil contained less potassium than ladino clover. Both of these legumes contained less potassium than the associated grass at all levels of potash treatment. Competition between the grass and legume for soil potassium appears to be greater in mixtures with alfalfa and birdsfoot trefoil. The data indicate that these two legumes were able to absorb less potassium at a given potash level than ladino clover. The effect of lime level on the precentage potassium in the forage was not apparent from these data.

The critical level of potassium (the level below which a significant reduction in yield from the maximum occurs) would appear to be in the range of 1.75 to 2.25 percent for alfalfa and birdsfoot trefoil. For ladino clover the level apparently is higher, around 2.5 percent. It is recognized that this varies with time of year and stage of growth. These studies suggest a potassium content of 2.5 to 3.0 percent for productive grasses. Smooth brome contained less potassium than orchardgrass in comparable treatments.

The content of potassium in the forage varied in general with the rates of potash applied.

Table 11.--Potassium content of the forage and total potassium removed from the soil in the first and second cutting, 1952

Fertilizer rate (Pounds per acre)		First cutting				Second cutting				Total K removed
		Grass		Legume		Grass		Legume		
P_2O_5	K_2O	K	K removed	K	K removed	K	K removed	K	K removed	
		Percent	Pounds	Percent	Pounds	Percent	Pounds	Percent	Pounds	Pounds
				Orchardgrass and Ladino Clover Mixture--High-Lime Level						
0	300	3.2	80	3.7	23	4.0	72	3.3	11	186
50	100	2.6	71	2.8	21	3.2	57	2.2	10	159
150	0	1.8	53	1.4	7	2.5	42	1.6	3	105
150	100	2.8	94	2.3	8	2.5	45	2.0	7	154
150	300	3.5	119	3.6	25	3.9	76	3.0	8	228
150 1/	100 1/	2.5	84	1.7	6	2.3	38	1.7	5	133
300 1/	300 1/	2.5	90	1.7	8	2.7	50	1.5	4	152
				Orchardgrass and Ladino Clover Mixture--Low-Lime Level						
0	300	3.5	67	4.0	27	4.2	59	3.5	15	168
50	100	3.3	78	2.9	21	3.6	55	2.8	11	165
150	0	2.4	65	1.8	9	2.7	43	1.8	5	122
150	100	3.2	75	2.8	23	3.7	62	2.4	9	169
150	300	3.6	93	4.2	36	4.2	72	3.2	12	213
150 1/	100 1/	2.4	55	2.2	13	2.9	37	2.0	8	113
				Tall Fescue and Ladino Clover Mixture--High-Lime Level						
0	300	3.3	55	3.5	41	3.2	24	3.0	30	150
50	100	2.9	53	2.8	29	3.1	21	2.5	25	128
150	0	2.5	50	1.8	13	2.4	17	2.0	21	101
150	100	2.8	67	2.6	32	3.0	23	2.5	49	171
150	300	3.4	88	3.7	40	3.5	27	3.2	37	192
150 1/	100 1/	2.6	71	2.2	15	2.7	37	2.1	18	141
				Smooth Brome and Alfalfa Mixture--High-Lime Level						
0	300	3.1	35	2.6	67	2.9	1	2.2	27	130
50	100	2.6	32	2.0	59	2.6	2	1.8	22	115
150	0	2.1	22	1.2	31	1.8	2	1.3	8	63
150	100	2.7	24	2.1	66	2.4	2	1.8	25	117
150	300	2.9	38	2.7	79	2.9	7	2.3	29	153
150 1/	100 1/	2.0	26	1.4	33	2.2	3	1.3	16	78
300 1/	300 1/	2.3	16	1.4	43	2.5	1	1.5	21	81
				Orchardgrass and Birdsfoot Trefoil Mixture--High-Lime Level						
0	300	3.6	74	3.4	57	4.0	43	2.6	9	183
50	100	2.9	60	1.7	35	3.5	33	1.8	6	134
150	0	2.5	55	1.0	14	2.7	32	1.5	5	106
150	100	2.8	59	2.0	54	3.4	40	2.0	6	159
150	300	3.9	105	2.6	45	4.0	48	1.9	6	204
150 1/	100 1/	2.7	53	1.2	21	3.1	29	1.5	6	109

1/ Applied the first year only.

The chemical data available from this study do not include the third, or final, cutting or the weed component of the forage. The total potassium removed from the soil (table 11), therefore, represents only the forage component of the first two cuttings. The data indicate that at the lower rates of potash over 100 percent of the applied potash had been removed by the first two harvests. At the high rate of potash, the potassium removal was about 60 to 70 percent of that applied. In the plots receiving 150 pounds of P_2O_5 and no K_2O each year, the total potassium removal was slightly over 100 to 120 pounds per acre in the first two harvests. This indicates that soil potassium, which was initially found to be about 158 pounds available K_2O per acre (table 1), was apparently being depleted rather rapidly. This was also indicated by rapidly declining yields after the first season.

The smooth brome and alfalfa mixture removed considerably less potassium than the mixtures containing ladino clover. The orchardgrass and birdsfoot trefoil mixture, although it removed more potassium than the brome and alfala mixture, usually removed less than the mixtures containing ladino clover. These differences can be partially explained on the basis of the percentage potassium in the plant material; however, the smooth brome and alfalfa and orchardgrass and birdsfoot trefoil mixtures did not reach their peak of production until 1953. Mixtures containing ladino clover produced at their peak in the first season, 1952.

Phosphorus

Phosphorus content of the plants varied in general with the amount of P_2O_5 applied (table 12). Ladino clover had a higher phosphorus content than the associated grasses with most treatments. Alfalfa and birdsfoot trefoil were lower in phosphorus content than ladino clover and also lower than the associated grasses. The data for the second cutting are not presented. However, the phosphorus content increased in all species except ladino clover and alfalfa.

The data indicate that the critical level of phosphorus in the species studied ranges from 0.20 to 0.30 percent.

Sodium

The sodium content of the forage was more variable than the other major elements (table 12). Ladino clover contained 5 to 10 times as much sodium as orchardgrass. Alfalfa and birdsfoot trefoil contained two to three times as much as the associated grass. Sodium content varied inversely with the rate of potash application; however, it was considerably lower on high-lime plots than on low-lime. Lime level appears to have less effect on the sodium content of the legumes than on the grasses.

Calcium

The legumes generally were found to contain 500 to 600 percent more calcium than the associated grass (table 12). Birdsfoot trefoil, however, was only 200 to 300 percent higher in calcium content than the associated grass.

Table 12.--Na, Mg, Ca, and P content of the harvested forage from the first cutting, 1952

Fertilizer rate (Pounds per acre)		Grass				Legume			
P_2O_5	K_2O	Na	Mg	Ca	P	Na	Mg	Ca	P
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Orchardgrass and Ladino Clover Mixture--High-Lime Level									
0	300	0.004	0.15	0.24	0.18	0.039	0.34	1.25	0.16
50	100	.008	.17	.28	.21	.075	.41	1.25	.24
150	0	.028	.18	.22	.26	.104	.47	1.85	.31
150	100	.008	.14	.21	.26	.081	.49	1.80	.31
150	300	.006	.16	.23	.25	.070	.38	1.15	.28
150 1/	100 1/	.006	.14	.19	.20	.112	.51	1.70	.19
300 1/	300 1/	.006	.18	.21	.20	.086	.57	1.80	.29
Orchardgrass and Ladino Clover Mixture--Low-Lime Level									
0	300	0.004	0.11	0.19	0.16	0.080	0.33	1.20	0.18
50	100	.013	.16	.30	.23	.086	.41	1.75	.24
150	0	.026	.16	.26	.29	.125	.45	1.65	.40
150	100	.010	.16	.27	.28	.117	.41	1.45	.37
150	300	.010	.14	.23	.24	.054	.31	1.15	.33
150 1/	100 1/	.015	.16	.24	.20	.100	.40	1.45	.27
Tall Fescue and Ladino Clover Mixture--High-Lime Level									
0	300	0.016	0.24	0.29	0.23	0.067	0.34	1.25	0.25
50	100	.013	.25	.26	.26	.065	.39	1.50	.32
150	0	.016	.26	.28	.31	.084	.42	1.70	.36
150	100	.016	.22	.24	.26	.077	.41	1.65	.32
150	300	.012	.26	.30	.30	.047	.37	1.30	.35
150 1/	100 1/	.019	.26	.28	.23	.088	.40	1.55	.28
Orchardgrass and Birdsfoot Trefoil Mixture--High-Lime Level									
0	300	0.004	0.19	0.29	0.23	0.007	0.31	0.76	0.14
50	100	.003	.17	.26	.27	.007	.34	.84	.17
150	0	.006	.17	.23	.32	.030	.43	.96	.24
150	100	.004	.19	.43	.30	.011	.33	.90	.26
150	300	.003	.20	.27	.26	.006	.21	.49	.17
150 1/	100 1/	.005	.20	.24	.24	.012	.39	.82	.16
Smooth Brome and Alfalfa Mixture--High-Lime Level									
0	300	0.004	0.11	0.46	0.19	0.006	0.25	1.10	0.15
50	100	.003	.11	.23	.26	.012	.33	1.20	.21
50	300	.004	.12	.26	.26	.006	.26	1.03	.22
150	0	.004	.21	.40	.35	.016	.52	1.80	.30
150	100	.004	.12	.27	.29	.011	.40	1.40	.24
150	300	.004	.11	.27	.27	.008	.25	1.12	.21
150 1/	100 1/	.006	.13	.28	.27	.019	.40	1.65	.25
300 1/	300 1/	.005	.15	.27	.27	.015	.34	1.00	.27

1/ Applied the first year only.

It contained about half as much calcium as ladino clover and alfalfa. Legumes from plots receiving 150 pounds of P_2O_5 without potash each year were higher in calcium content than those from plots receiving potash. The difference in calcium content between the grasses and legumes decreased considerably in the second cutting. Legumes declined in calcium content as the grasses tended to increase. Tall fescue showed the largest increase in the second cutting.

In studies with prepared homionic soils of various exchangeable Ca-K equivalent ratios, Hunter, Toth, and Bear (17) showed that when the Ca-K equivalent ratios in the alfalfa tops exceeded 4:1, the yields without exception were markedly depressed. Their data also indicated that whenever the percentage of calcium in plants exceeded 2 or the potassium fell below 1 the yields tended to drop abruptly. Data from the present study indicate that the Ca-K equivalent ratio was generally well below 1:1 in all treatments except the ladino clover that received no potash fertilizer or 100 pounds per acre the first year only. In these treatments the ratios were approximately 1.75:1 and yields were greatly reduced. The Ca-K ratios in orchardgrass ranged from 0.15:1 at the highest rates of potash to 0.25:1 in plots receiving no potash.

Magnesium

Walsh and O'Donohoe (37) reported that the magnesium uptake decreases as level of potassium fertilization is increased. More recent research, reported subsequent to the completion of the present studies, have shown a similar reduction in magnesium uptake with increased potassium fertilization (6, 12). In the present studies there was some evidence of this relationship, but the effect was not of the same magnitude nor so consistent as some have reported. It was most evident in alfalfa.

The legumes contained two to three times as much magnesium as grasses in the first cutting. Tall fescue was somewhat higher in magnesium content than the other grasses and was only 50 to 60 percent lower than the legumes.

Most of the values for magnesium fell between 0.35 and 0.45 percent in the legumes. For orchardgrass the range was approximately 0.15 to 0.20 percent, and for tall fescue, 0.20 to 0.25 percent. Most of the smooth brome samples contained only 0.11 to 0.12 percent magnesium.

The magnesium content of the grasses increased in the second cutting, but there was only a slight increase in the legumes. This resulted in magnesium contents that were almost the same in the grasses and legumes in the tall fescue and ladino clover and the smooth brome and alfalfa mixtures.

K/(Ca + Mg) Equivalent Ratios

A nutritional disorder in cattle and sheep known as grass tetany has received considerable attention from animal physiologists and nutritionists in the past few years. The disorder is often characterized by lowering of the magnesium content of the blood serum in the animal, often ending in death.

Wide differences of opinion exist on causes of the malady.

Much pertinent literature relative to hypomagnesaemia and fertilization has been published subsequent to the completion of the field studies reported here. The literature citations therefore contain many of these more recent research findings.

Results of research in some countries have suggested that hypomagnesaemia is related to high nitrogen and potassium applications, which result in herbage with a high potassium content (5, 18, 20, 30). Pastures in most of the countries that have experienced these disorders are composed primarily of grasses and are almost devoid of clovers (9). Seekles (29) and Cuthbertson (9) presented detailed discussions on hypomagnesaemia. The lack of agreement in the research findings indicates that the problem is very complex.

Wolton (42) indicated that potash applications should be lower and that more legume in the herbage should be encouraged. Wolton showed that clovers contain 1.5 times as much magnesium as grasses. Approximately this same relationship was found between grasses and legumes in the present study (table 12).

Welte (40), however, considers this change in potassium content of the plants brought about by potassium fertilizers of no importance from the standpoint of physiologically overloading the animal with potassium.

It has been indicated that high nitrogen and potassium fertilization not only resulted in high potassium contents of the forage but also in a significant lowering of the magnesium content in the forage and in the blood serum (6, 9, 38).

Inglis' (19) observations failed to show a correlation between magnesium content of herbage and the fluctuations in serum magnesium values.

Some investigators have reported that high incidence of hypomagnesaemia was found to be associated with high values, or ratios, of K/(Ca + Mg) (5, 18, 20). Wind (41) reported the relationship between the equivalent ratios of K/(Ca + Mg) in the herbage grazed by 6,566 milking cows and the incidence of nutrition tetany. At K/(Ca + Mg) ratios in the pasture from <1.01 to 1.80, nutrition tetany was found very seldom. Only 1 cow in 2,604, or 0.04 percent, suffered from tetany. At a ratio from 1.81 to 2.20, 35 out of 2,051 milking cows or 1.07 percent, showed tetany. At a ratio of 2.21 to 2.60, the incidence was 54 out of 1,054, or 5.1 percent. At a ratio of 2.61 to 3.00, 49 out of 716 cows, or 6.8 percent, showed tetany; at ratios greater than 3.00, 24 out of 138 cows, or 17.4 percent, were affected.

Horst, as cited by Seekles (29), however, found no close relationship between hypomagnesaemia and the K/(Ca + Mg) ratio in the grass.

Since some studies have indicated that K/(Ca + Mg) equivalent ratios in excess of 2 to 2.5 may cause hypomagnesaemia, it may be of interest to examine the data from this study to determine the effect of some of the treatments on this ratio.

The K/(Ca + Mg) equivalent ratios in the grasses and legumes from tall fescue and ladino clover, orchardgrass and ladino clover, and smooth brome and alfalfa mixtures are presented (table 13). The data indicate that the K/(Ca + Mg) equivalent ratios in the grasses were several times higher than those in legumes. Generally, orchardgrass had the highest ratios of the three grasses and tall fescue the lowest. Ladino clover and alfalfa did not appear to differ appreciably.

Table 13.--Equivalent ratios of potassium to calcium and magnesium [K/(Ca + Mg)] in the harvested forage, 1952

Fertilizer rate (Pounds per acre)		First cutting of--				Second cutting of--			
		Grass		Legume		Grass		Legume	
P_2O_5	K_2O	High lime	Low lime	High lime	Low lime	High lime	Low lime	High lime	Low lime
Orchardgrass and Ladino Clover Mixture									
0	300	3.28	4.74	1.04	1.16	2.86	2.84	0.93	1.11
50	100	2.39	3.04	.74	.61	1.71	2.09	.58	.80
150	0	1.77	2.38	.27	.38	1.23	1.44	.35	.46
150	100	3.13	3.04	.45	.67	1.14	2.38	.46	.60
150	300	3.60	3.83	1.02	1.29	2.44	2.92	.84	.96
150 1/	100 1/	2.91	2.48	.34	.53	1.05	1.57	.42	.52
Smooth Brome and Alfalfa Mixture									
0	300	2.47	----	0.88	----	2.47	----	0.97	----
50	100	3.19	----	.58	----	1.97	----	.78	----
150	0	1.42	----	.23	----	.96	----	.41	----
150	100	2.88	----	.52	----	1.72	----	.73	----
150	300	3.22	----	.97	----	2.24	----	1.09	----
150 1/	100 1/	2.04	----	.30	----	1.27	----	.48	----
300 1/	300 1/	2.19	----	.46	----	1.52	----	.55	----
Tall Fescue and Ladino Clover Mixture									
0	300	2.43	----	0.99	----	1.61	----	0.90	----
50	100	2.18	----	.67	----	1.49	----	.67	----
150	0	1.78	----	.38	----	.89	----	.48	----
150	100	2.40	----	.57	----	1.26	----	.69	----
150	300	2.35	----	.99	----	1.80	----	.98	----
150 1/	100 1/	1.86	----	.50	----	1.28	----	.55	----

1/ Applied the first year only.

The K/(Ca + Mg) equivalent ratios varied with rate of potash application. Generally, the ratios were higher as potash applications increased. The ratios in orchardgrass ranged from 3.60 for high-potash to 1.77 for no-potash treatments at the high-lime level. The ladino clover ranged from 1.04 for high-potash to 0.27 for no-potash treatments at the high-lime level. The low-lime level, generally, produced considerably higher ratios than the high-lime level. This suggests that dolomitic limestone may be somewhat effective in reducing the K/(Ca + Mg) ratio. The second-cutting forage usually produced much lower ratios than the first cutting.

If it is assumed that the critical upper level for the equivalent ratio of K/(Ca + Mg) is >2.00 to 2.50, the orchardgrass from the first cutting would appear to be above this critical upper limit in all but the low-potash treatments. Except at the 300-pound rate of potash annually, the ratio in the grass at the second cutting was generally below this critical level.

The ratios in tall fescue and smooth brome were well below 2.50, except in smooth brome at the 300-pound rate of potash. In no case did the ratios in alfalfa or ladino clover approach the critical level.

These K/(Ca + Mg) equivalent ratios, when calculated on the total forage (grasses and legumes combined in their actual proportions), were generally found to be below or near the 2.50 level. The orchardgrass plots at the 300-pound rates of potash were still near the critical level of 2.50.

Micronutrients

The micronutrient content of the forage was changed very little by fertilizer treatment (Appendix table 14).

The copper content of the legumes was almost twice that of the grasses. Iron, aluminum, and boron were all much higher in the legumes than in the associated grasses. Iron and aluminum were about three to six times higher in ladino clover than in orchardgrass. Boron was two to three times higher in legumes than in the associated grasses.

Manganese was considerably lower in ladino clover than in orchardgrass. Tall fescue and smooth brome contained only about a third as much manganese as orchardgrass. The lime levels did not appear to affect the manganese content in any of the species as much as was expected. There was only a slight increase in manganese at the low-lime level. The manganese content of ladino clover grown with tall fescue was considerably lower than in that grown with orchardgrass.

Crude protein content of the forage is presented in Appendix table 15.

Summary

The potassium content of the forage increased as the rate of potash fertilizer was increased. Grasses generally contained more potassium than the associated legume except at the 300-pound rate of potash in the mixtures containing ladino clover. The potassium content was higher in ladino clover than in alfalfa or birdsfoot trefoil.

The critical level of potassium (the level below which a significant reduction in yield from the maximum occurs) would appear to be in the range of 1.75 to 2.25 percent for alfalfa and birdsfoot trefoil. For ladino clover the level apparently is higher, around 2.5 percent. It is recognized that this varies with time of year and stage of growth. These studies suggest a potassium content of 2.5 to 3.0 percent for productive grasses. Smooth brome contained less potassium than orchardgrass in comparable treatments. The data indicate that the forage mixtures were removing approximately 100 percent of the applied potassium.

The phosphorus content of the plants varied in general with the amount of P_2O_5 applied. Ladino clover had a higher phosphorus content than the associated grasses with most treatments. Alfalfa and birdsfoot trefoil were lower in phosphorus content than ladino clover and the associated grasses. The data indicate that the critical level of phosphorus in the species studied range from 0.20 to 0.30 percent.

Legumes generally contained several times more calcium than the associated grass. Calcium content of the plants was reduced by potash fertilization.

Most of the values for magnesium fell between 0.35 and 0.45 percent in the legumes. For orchardgrass the range was approximately 0.15 to 0.20 percent, and for tall fescue, 0.20 to 0.25 percent. Most of the smooth brome samples contained only 0.11 to 0.12 percent magnesium.

The K/(Ca + Mg) equivalent ratios, which have been identified by some workers with grass tetany in ruminants, were determined. Usually these ratios were lower than 2.5 in the combined grass and legume forage. Orchardgrass contained ratios that were in excess of 2.5 with the high-potash treatments. Tall fescue had ratios less than 2.5 in all treatments and was considerably lower than that of orchardgrass. The legumes all contained very low ratios.

SUMMARY

The effect of rates and ratios of phosphorus and potassium fertilizers and lime levels on forage yield and botanical and chemical composition of seven grass-legume mixtures was studied over a 3-year period.

Potassium fertilization produced the greatest yield response in all the forage mixtures. It was necessary to apply 100 to 300 pounds of K_2O per acre to maintain good yields of the mixtures. Smooth brome and alfalfa showed the most outstanding response to potassium. There was very little residual effect from the application of high rates of potassium the first year only.

Phosphate needs appeared to be satisfied with the application of 150 pounds of P_2O_5 per acre at seeding or about 50 pounds per acre annually.

The most striking response to lime level was shown by the smooth brome and alfalfa mixture. Alfalfa was eliminated almost completely from the mixture during the first season at low-lime levels. The orchardgrass and birdsfoot trefoil mixture was the only one that showed a consistent favorable response to low-lime levels.

The balance of legumes and grasses changed considerably during the 3 years of the study. Potassium application maintained the percentage of legumes at a higher level. The legume percentage in plots fertilized at the lower rates of potassium or with high rates the first year only began to decline rapidly after the first year. Yields decreased generally as the proportion of legumes decreased.

The potassium and phosphorus content of the forage varied in general with the amount of the elements applied. Grasses were generally higher in potassium content than legumes except at the highest rates of potassium application. Ladino clover contained more potassium than alfalfa or birdsfoot trefoil. The critical level of potassium would appear to be from 1.75 to 2.25 percent for alfalfa and birdsfoot trefoil and about 2.5 percent for ladino clover. The grasses should contain about 2.5 to 3.0 percent potassium for good production.

The K/(Ca + Mg) equivalent ratios usually were lower than 2.5 in the combined grass and legume forage. Orchardgrass alone at high rates of potash fertilization would contain ratios in excess of 2.5.

Data on the content of other major and minor elements in individual grass and legume species were ~~are~~ presented.

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Table 14.--Micronutrient composition of forage in first cutting, 1952

Fertilizer rate (Pounds per acre)		Grass					Legume				
P_2O_5	K_2O	Cu	Mn	Fe	Al	B	Cu	Mn	Fe	Al	B
		p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
Orchardgrass and Ladino Clover Mixture--High-Lime Level											
0	300	48	238	62	52	15	20	108	225	305	31
50	100	59	245	88	88	11	41	98	205	215	29
150	0	61	240	67	65	9	35	135	250	335	30
150	100	48	240	70	59	10	25	150	275	315	37
150	300	74	265	83	66	10	23	95	200	205	34
150 1/	100 1/	68	225	58	49	9	32	115	300	420	30
Orchardgrass and Ladino Clover Mixture--Low-Lime Level											
0	300	63	310	60	46	9	28	155	205	245	32
50	100	83	255	68	55	8	24	135	215	245	32
150	0	80	250	99	78	9	46	175	235	285	36
150	100	65	250	73	59	11	47	140	200	225	38
150	300	63	250	70	58	8	51	125	165	200	31
150 1/	100 1/	65	225	60	47	8	53	120	215	235	35
Tall Fescue and Ladino Clover Mixture--High-Lime Level											
0	300	54	85	125	175	16	67	64	210	255	41
50	100	52	80	91	74	13	52	77	195	215	39
150	0	59	78	93	85	11	20	80	215	185	41
150	100	66	80	88	74	11	43	84	215	280	36
150	300	57	83	115	110	17	47	63	225	290	34
150 1/	100 1/	46	63	85	93	10	48	77	195	205	39
Orchardgrass and Birdsfoot Trefoil Mixture--High-Lime Level											
0	300	35	240	111	76	11	39	79	150	148	23
50	100	43	230	69	51	11	17	62	115	100	24
150	0	50	185	70	43	11	22	77	140	97	24
150	100	34	255	98	60	12	49	70	270	135	20
150	300	36	250	115	71	10	12	60	108	87	18
150 1/	100 1/	62	290	72	51	9	39	82	140	98	26
Smooth Brome and Alfalfa Mixture--High-Lime Level											
0	300	74	88	71	62	9	35	59	145	150	32
50	100	55	76	83	46	17	39	50	118	93	35
50	300	78	82	83	59	12	31	48	125	79	35
150	0	78	92	110	67	12	34	65	145	98	31
150	100	73	68	103	71	16	25	60	128	71	27
150	300	85	80	82	57	13	31	48	115	90	26
150 1/	100 1/	70	78	85	62	10	27	66	180	93	35

1/ Applied the first year only.

Table 15.--Protein content of the forage, 1952

Fertilizer rate (Pounds per acre)		Grass		Legume	
P_2O_5	K_2O	First cut	Second cut	First cut	Second cut
		Percent	Percent	Percent	Percent
Orchardgrass and Ladino Clover Mixture--High-Lime Level					
0	300	8.12	14.84	23.28	19.85
50	100	7.71	15.05	25.12	20.20
150	0	9.08	13.93	25.82	22.97
150	100	8.77	14.92	26.02	17.74
150	300	8.70	14.00	23.79	20.21
150 1/	100 1/	8.33	15.81	23.77	21.72
Orchardgrass and Ladino Clover Mixture--Low-Lime Level					
0	300	9.81	14.27	23.34	19.77
50	100	9.52	14.23	25.05	20.50
150	0	9.05	14.93	26.60	22.02
150	100	9.39	14.31	25.70	20.88
150	300	9.18	13.99	24.15	20.30
150 1/	100 1/	9.12	14.70	25.54	21.41
Tall Fescue and Ladino Clover Mixture--High-Lime Level					
0	300	11.00	15.61	25.18	21.07
50	100	10.07	16.34	26.46	21.30
150	0	11.56	16.29	27.46	22.66
150	100	11.30	15.99	25.77	21.85
150	300	12.81	15.54	26.96	20.53
150 1/	100 1/	11.04	15.83	27.92	21.84
Orchardgrass and Birdsfoot Trefoil Mixture--High-Lime Level					
0	300	7.80	18.49	15.81	16.36
50	100	7.41	18.99	14.85	17.76
150	0	8.91	18.77	16.40	16.51
150	100	8.32	18.06	16.23	17.24
150	300	8.52	18.36	16.35	19.52
150 1/	100 1/	8.76	18.61	17.27	17.89
Smooth Brome and Alfalfa Mixture--High-Lime Level					
0	300	6.22	18.00	16.62	15.37
50	100	6.30	17.17	16.85	16.32
50	300	7.21		18.06	
150	0	7.08	20.56	19.35	15.91
150	100	6.64	19.51	17.21	17.33
150	300	7.39	17.33	20.35	16.09
150 1/	100 1/	4.15	18.89	19.39	15.79

1/ Applied the first year only.